Light-Duty Vehicle Choice Modeling and Benefits Analysis

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National Renewable Energy Laboratory (NREL)
6/2/2020

DOE Vehicle Technologies Program
2020 Annual Merit Review and Peer Evaluation Meeting

Project ID # van018

Overview

Timeline

- Project start date: 10/01/2019
- Project end date: 09/30/2022
- Percent complete: 20%

Budget

- Total project funding: $900K (pending future appropriations)
  - DOE share: 100%
- Funding for FY 2019: N/A
  - Though this project builds upon previous activities
- Funding for FY 2020: $300K

Barriers

- Rigorous modeling and applied analysis needed to assess program benefits and inform portfolio planning related to:
  - Advanced Combustion
  - Electrification Technologies
  - Batteries
  - Material Technologies
  - Fuel Cells
  - Hydrogen Storage

Partners

- Project lead: NREL
- Argonne National Laboratory
- DOE technology managers

Relevance

Objective: Estimate the energy and emission benefits of vehicle technology research

- Vehicle electrification, including batteries, motors and power electronics
- Combustion and materials
- Fuel cells and hydrogen storage

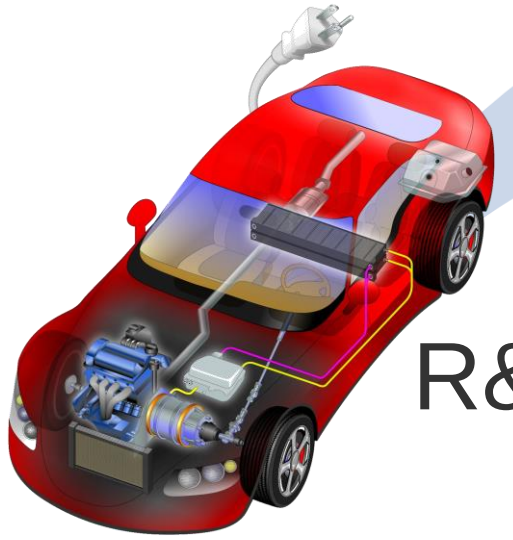
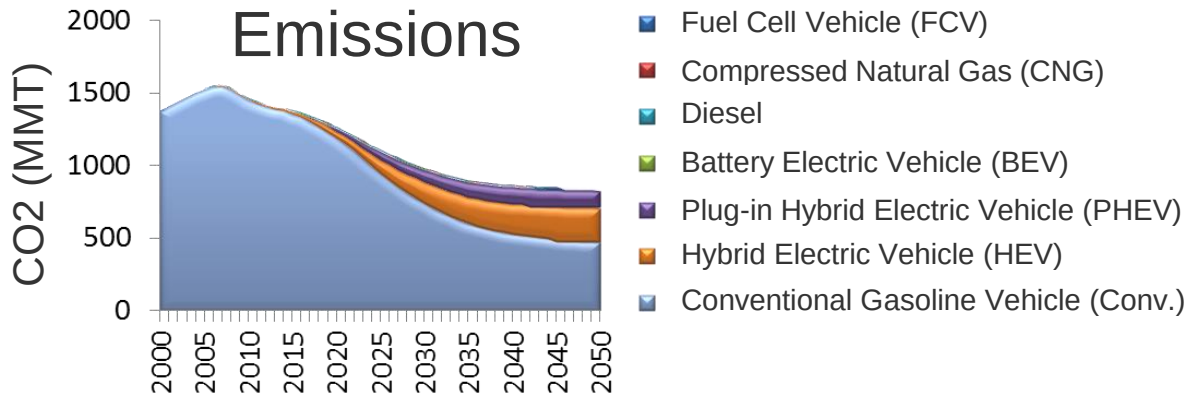
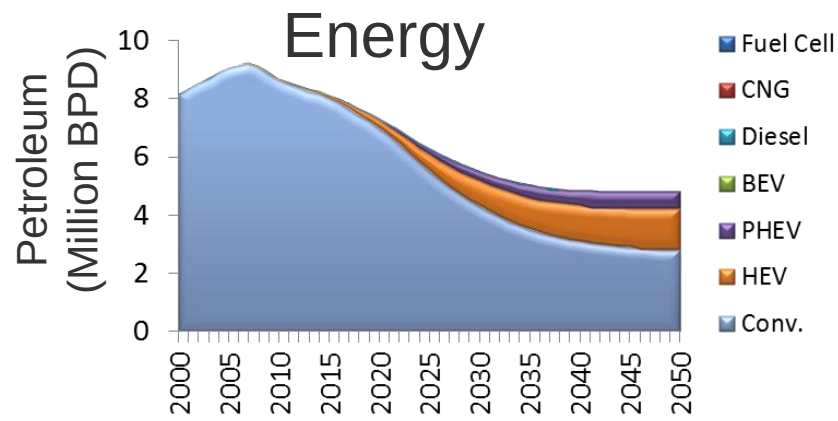


Image by Jim Snyder, NREL

R&D

Benefits

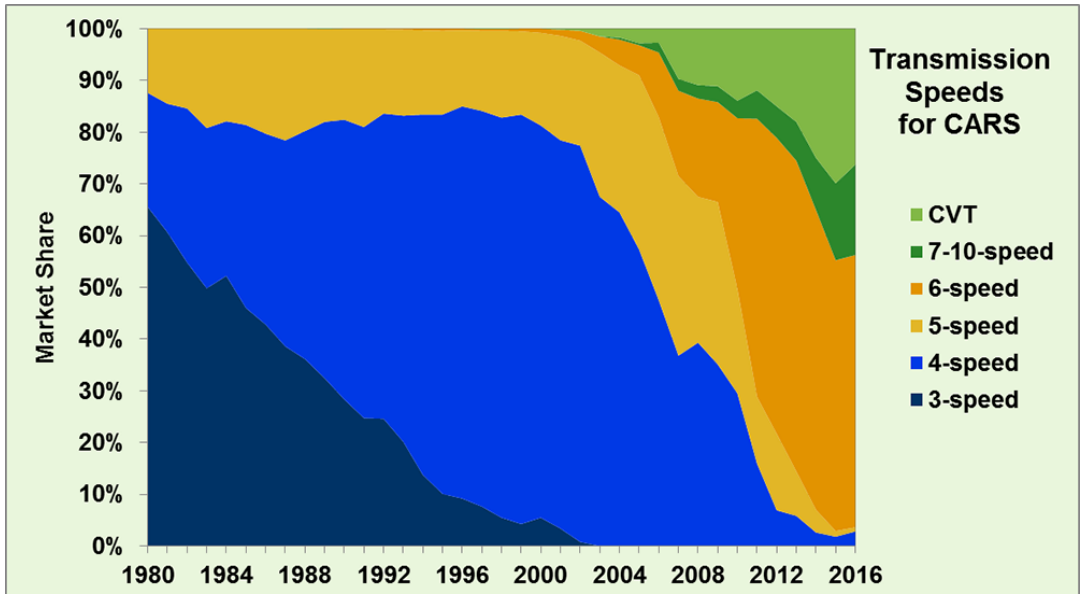




BPD: barrels per day
MMT: million metric tons
R&D: research and development

FY2020 Milestones/Accomplishments

- ✓ Q1: Update DOE on Light Duty Automotive Deployment Options Projection Tool (ADOPT) enhancements.
  - ✓ Improved transmission modeling to capture trend of increasing number of speeds
  - ✓ Added automatic inflation adjustment to sync prices of different data sets
  - ✓ Improved long-distance range penalty for BEVs
  - ✓ Heavy-duty data and model improvements
- ✓ Q2: Share preliminary light-duty (LD) benefits analysis runs with DOE for review and feedback.
  - ✓ Electrification
  - ✓ Combustion
  - ✓ Materials
  - ✓ Fuel cells and Hydrogen Storage
- Q4: Ongoing
  - Deliver completed LD Benefits Analysis Report for final DOE review.
  - Go/No-Go: Confirm success of streamlined process and assess priorities for FY21, including refining/updating input assumptions and model features.



Source: Oak Ridge National Laboratory, *2016 Vehicle Technologies Market Report*, May 2017.

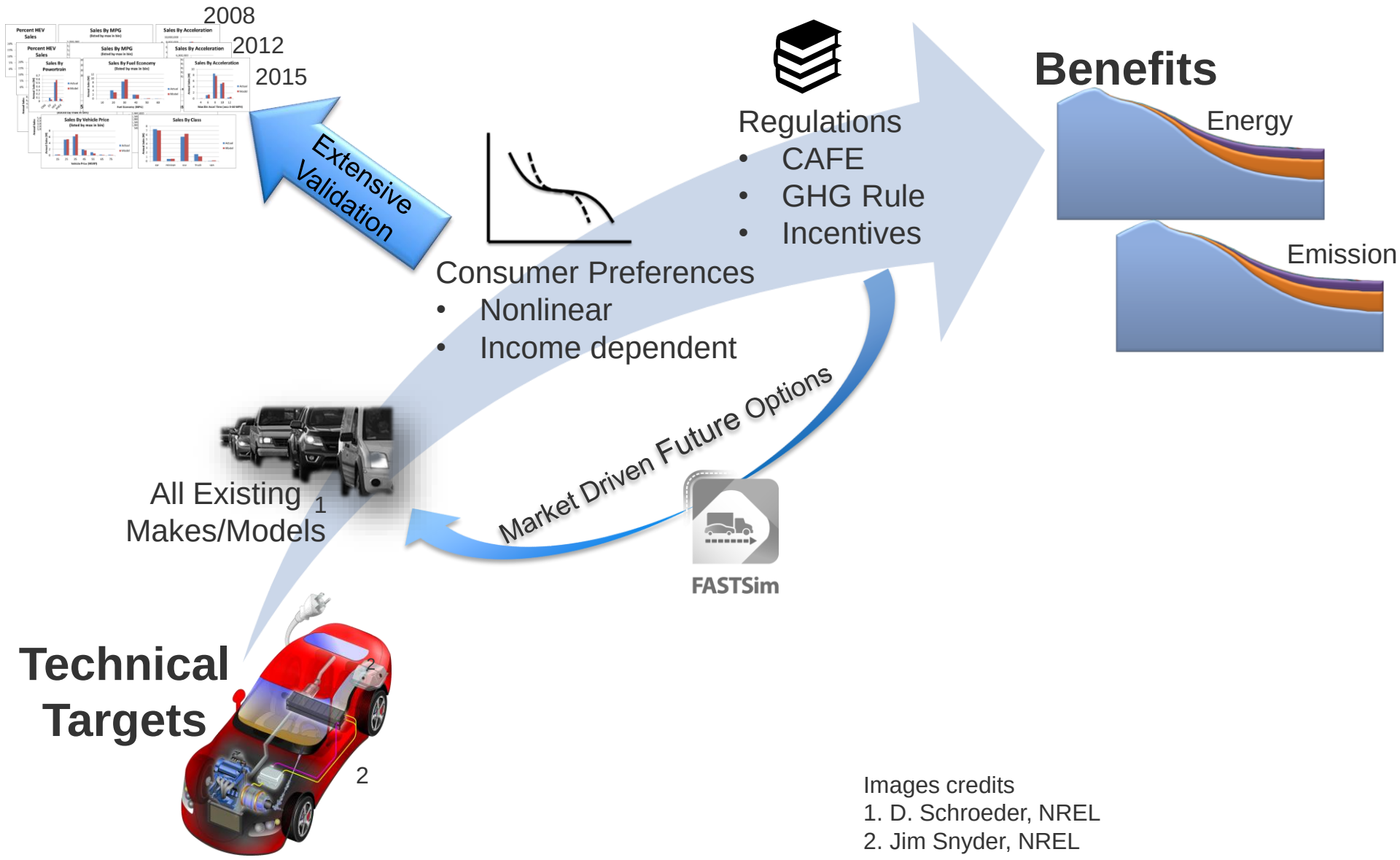
Approach

- Use ADOPT to estimate R&D energy and emission benefits
  - Improve model
  - Implement 2019 technical targets
  - Run No Program scenario
  - Compare to technology success scenarios

- Review results with VTO, HFTO, BETO

- Discuss target updates and rerun as needed

Approach: ADOPT

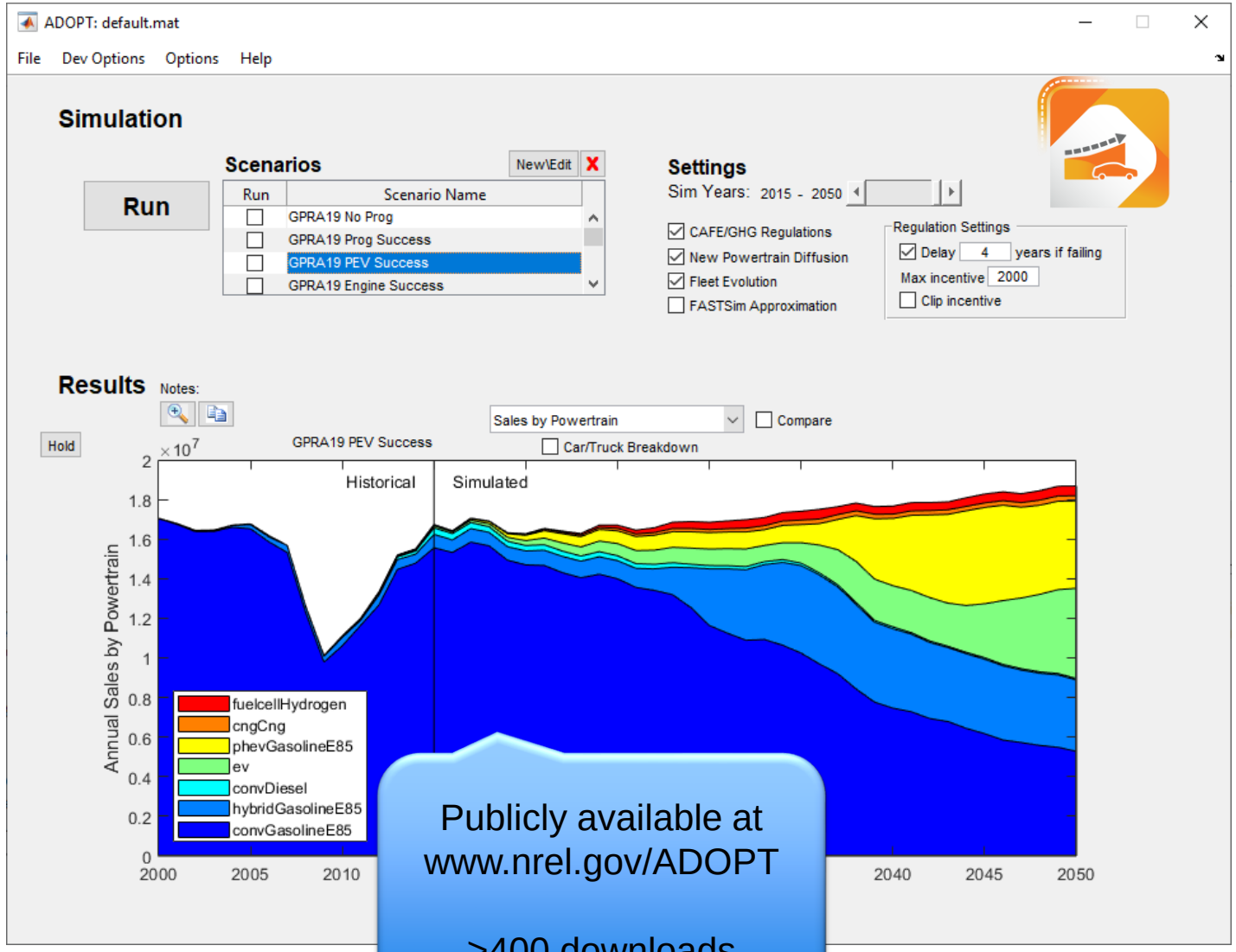


Images credits
1. D. Schroeder, NREL
2. Jim Snyder, NREL
FASTSim: Future Automotive Systems Technology Simulator

Approach: ADOPT

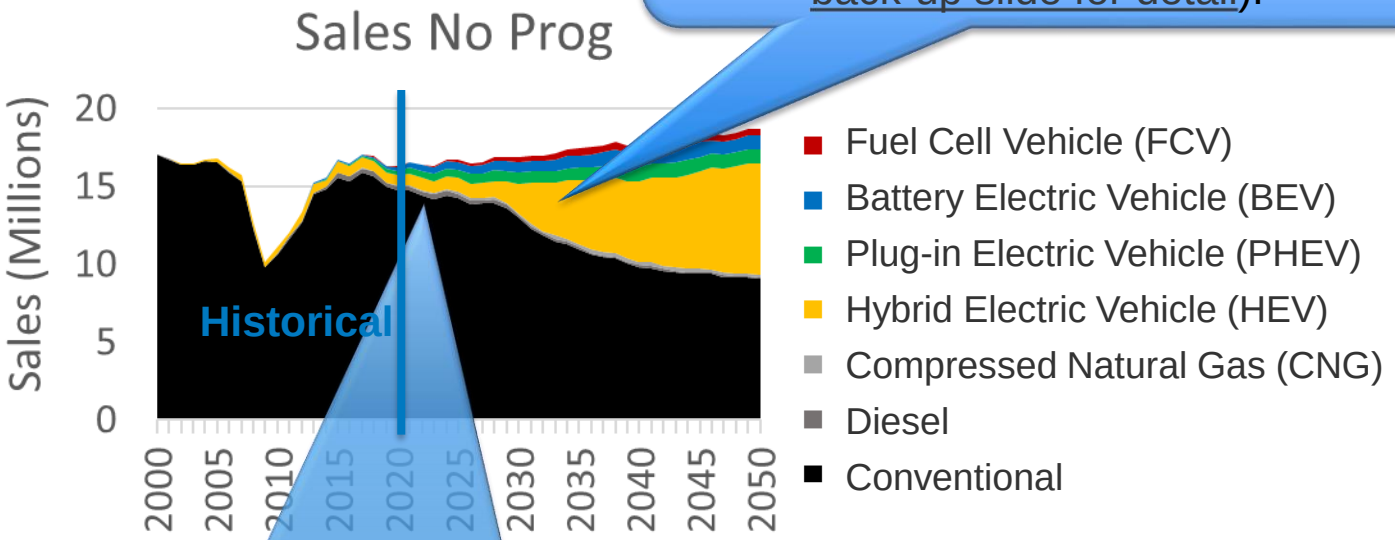
Structured and efficient approach

- A user interface provides
  - Easy input and vetting (charts) of technical targets and assumptions
  - Data management of scenarios
  - Extensive review of results
- Endogenously creates future vehicle options unique to each scenario
  - Optimizes vehicle component sizes (engine power, battery energy, etc.) to achieve the best combination of vehicle attributes for different income levels
- Runs each scenario in 1–4 hours overnight (hundreds of thousands of FASTSim runs)

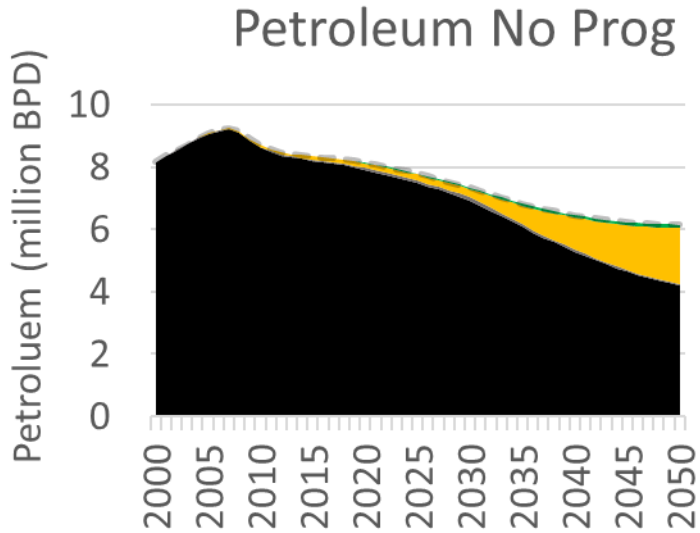


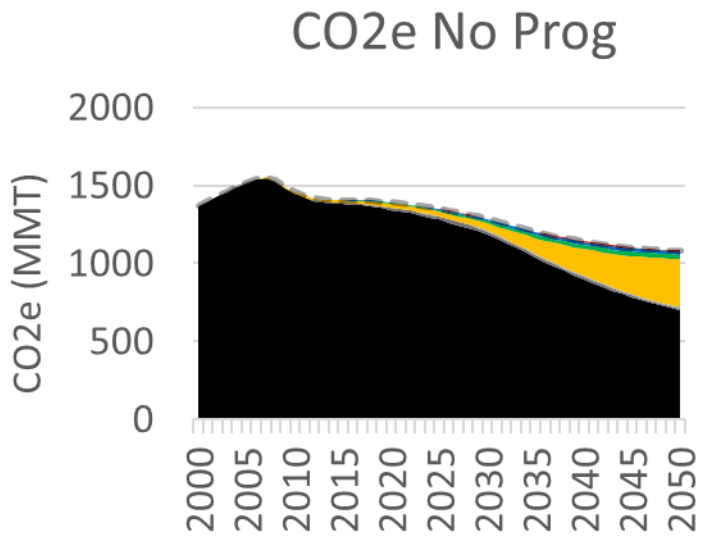
Accomplishment: Preliminary No Program Results

HEVs enter later as battery cost drops enough to make performance options at mass market prices (see technical back-up slide for detail).



Near-term, most sales continue to be conventional vehicles because of their low price, reasonable acceleration, high range, and quick refueling (see technical back-up slides for details).





No Program
Program Success

Batteries	PEEM	Combustion	Materials	Fuel Cells	H2 Storage

PEEM: Power electronics and electric machines

H2: hydrogen

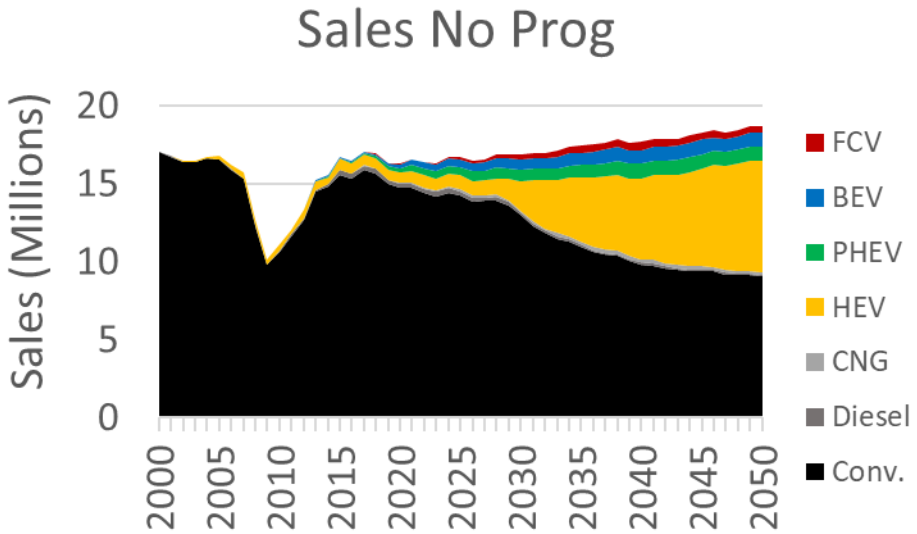
Electrification Success Using 2019 Assumptions

(also completed for combustion, materials, fuel cells and hydrogen storage)

Technical Accomplishments and Progress

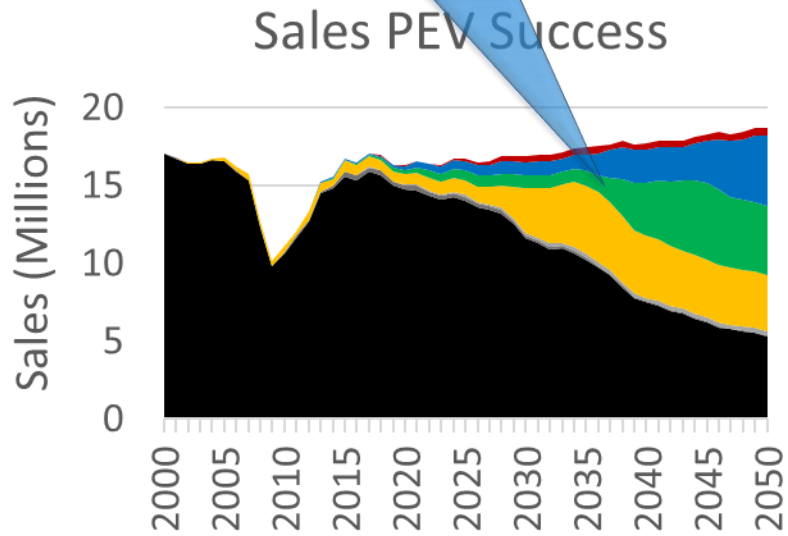
No Program						
Program Success	**Batteries**	**PEEM**	**Combustion**	**Materials**	**Fuel Cells**	**H2 Storage**

Accomplishment: Preliminary Electrification Success Sales Comparison



HEVs enter first again, but then PHEVs with quick acceleration at a mass market price as battery cost drops to $130/kWh (see technical back-up slides).

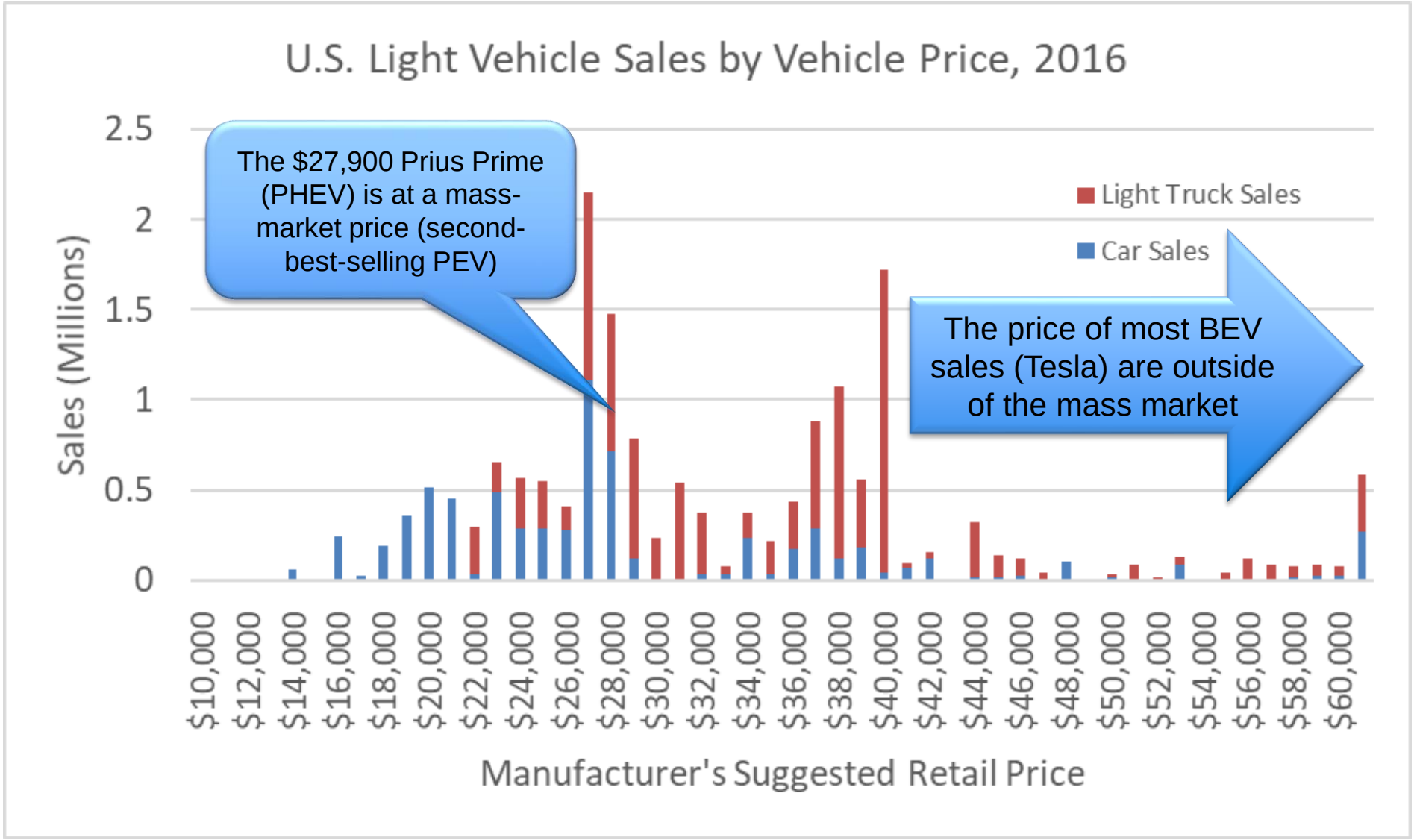
Electrification Success



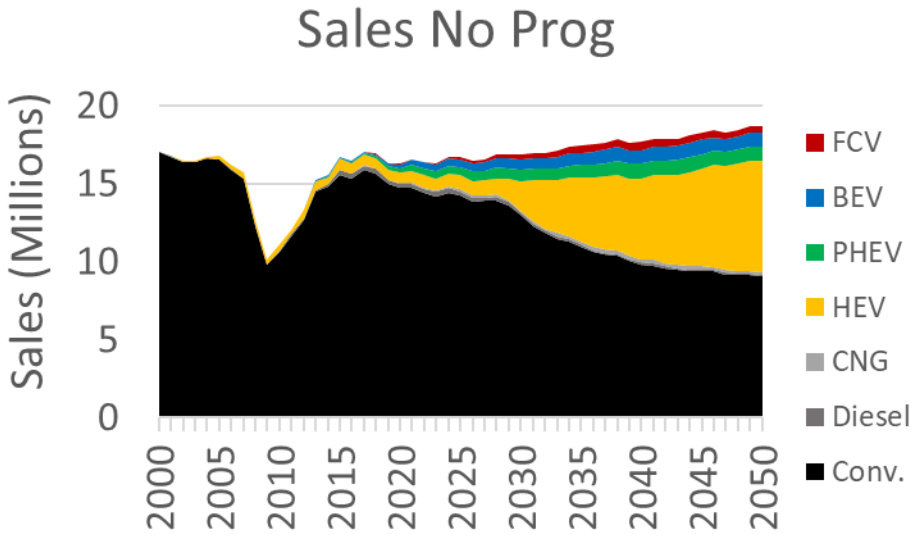
No Program
Program Success

Batteries	PEEM	Combustion	Materials	Fuel Cells	H2 Storage

Accomplishment: Checked that Mass Market PHEV Results are Supported by Sales Trends



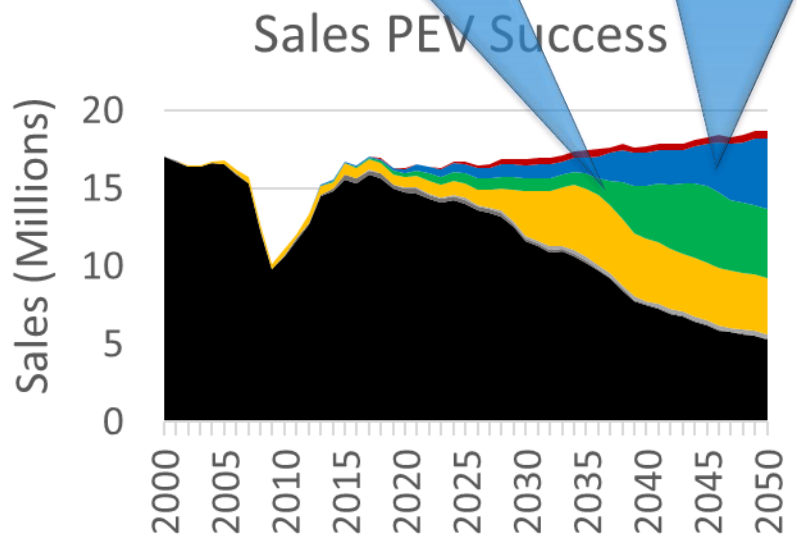
Accomplishment: Preliminary Electrification Success Sales Comparison



HEVs enter first again, but then PHEVs with quick acceleration at a mass market price as battery cost drops to $130/kWh (see technical back-up slides).

BEVs enter when battery cost drops to $80/kWh and can provide good range and quick acceleration at a mass market price.

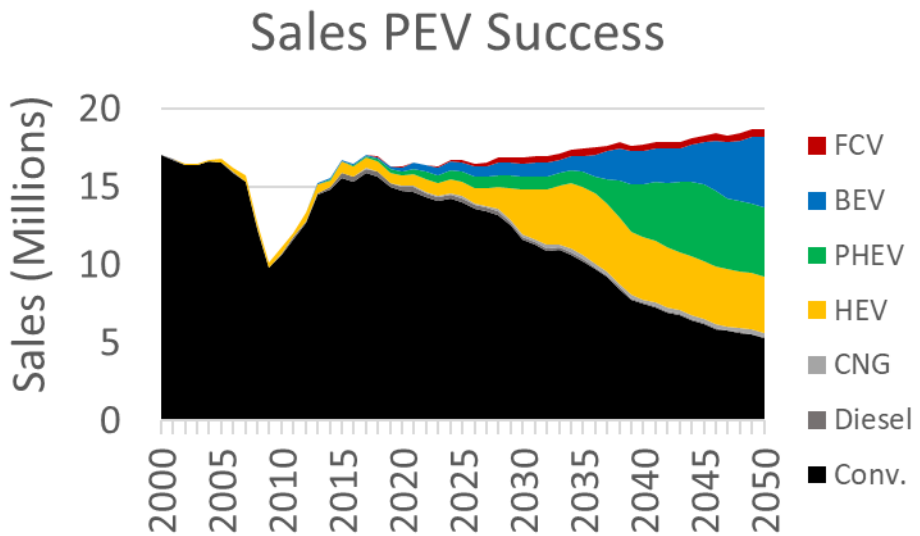
Electrification Success

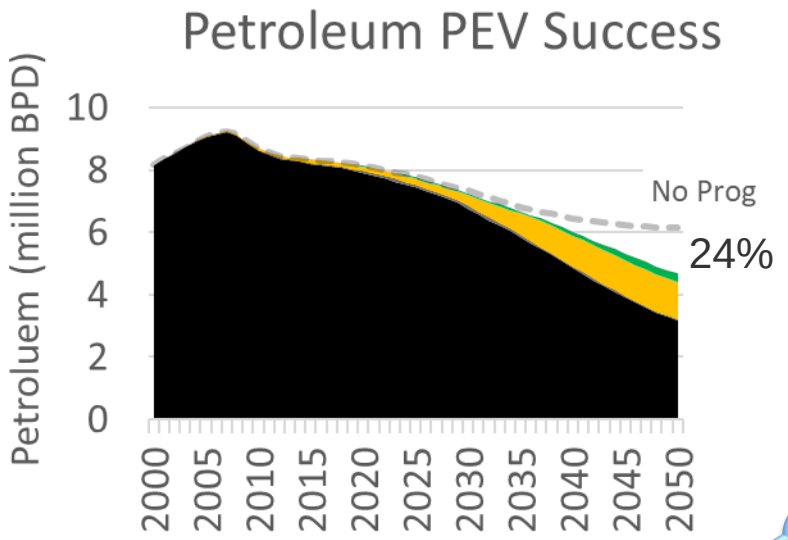


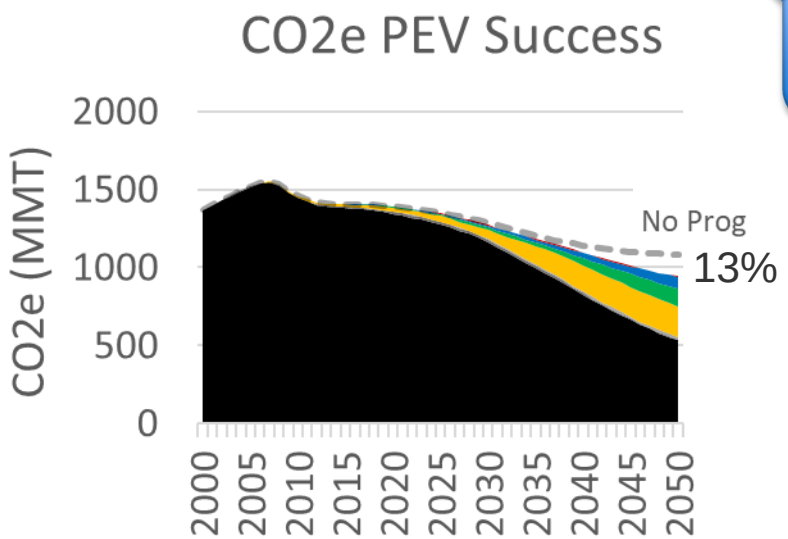
No Program
Program Success

Batteries	PEEM	Combustion	Materials	Fuel Cells	H2 Storage

Accomplishment: Preliminary Electrification Benefits Results





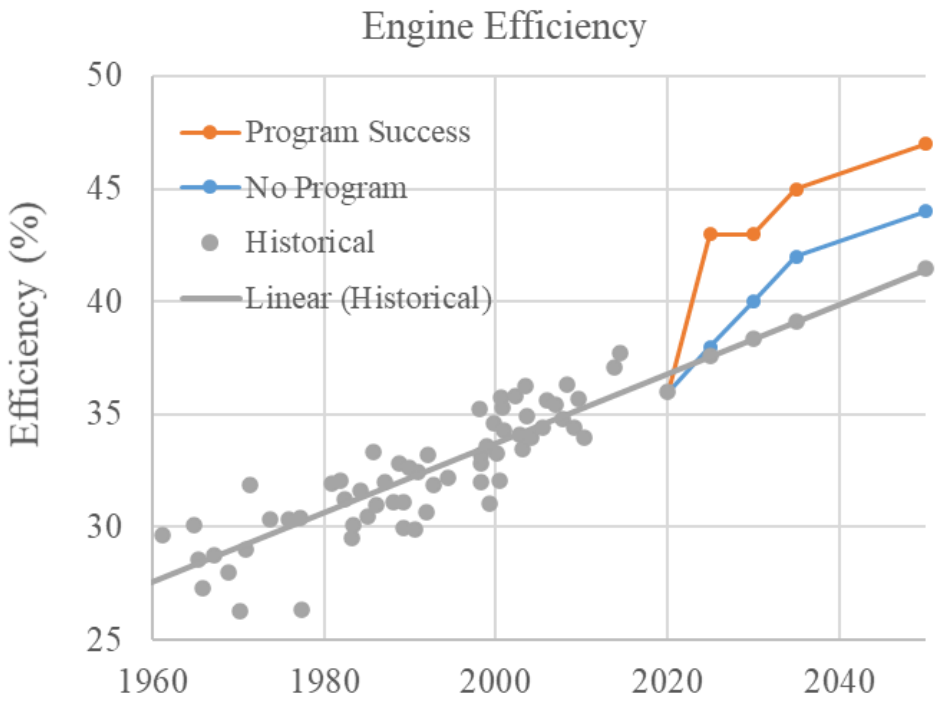


24% energy and 13% emission benefits

No Program
Program Success

Batteries	PEEM	Combustion	Materials	Fuel Cells	H2 Storage

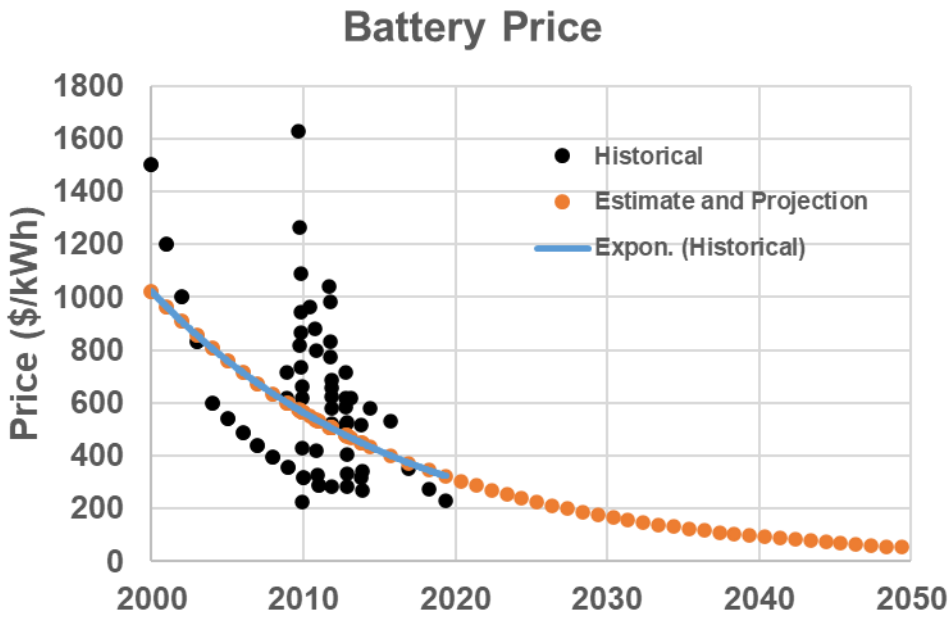
Accomplishment: Collected Historical Data



Takahashi, D., Nakata, K., Yoshihara, Y., and Omura, T., "Combustion Development to Realize High Thermal Efficiency Engines," SAE Int. J. Engines 9(3):1486-1493, 2016, https://doi.org/10.4271/2016-01-0693.

Collected historical data to help inform target update discussions

- Battery cost
- Engine efficiency
- Motor cost
- Power electronics cost



Nykvist, B. and Nilsson, M. 2015. “Rapidly falling costs of battery packs for electric vehicles.” *Nature Climate Change* 5: 329–332. https://doi.org/10.1038/nclimate2564.

Responses to Previous Year Reviewers' Comments

Constructive comments from last review of this project (performed by another lab)

- "…it would be useful to look at program success scenarios one at a time for individual technology/subprogram targets…"
  - Implemented to show the value of each technology area, and the program robustness
- "…identify whether additional synergies may exist within the program investments."
  - We ran scenarios (most not shown) that evaluate potential synergies, such as including material success with electrification (was not synergistic because it helps conventional vehicles more)
- "…explore sensitivity to fuel costs also seems critical…"
  - Included in next steps

Collaboration and Coordination with Other Institutions

- Working with ANL (Thomas Stephens, Aymeric Rousseau)
  - ANL provided useful background knowledge, experience, previous technical targets, and results
  - Compared sales and benefits results
  - Updated analysis based on their input and feedback
  - Comparing ADOPT/FASTSim's vehicles with Autonomie
- Ongoing meetings with VTO, BETO, and HFTO technology managers on
  - 2019 targets and benefits results
  - Updates to those targets
- Technology managers are interfacing with industry for input on targets
- Collaborating with heavy-duty vehicle effort (NREL's Alicia Birky)

Remaining Challenges and Barriers

- Capturing home charging availability
  - Many households have home charging, but not all
  - Need to capture additional cost for those that do not
- Breaking out preferences for multivehicle households
  - Households having a second, longer-range vehicle may be more open to purchasing a shorter-range BEV
- Considering changes to transportation and household paradigms
  - How significant are the trends in telecommuting (now with COVID-19)?
  - Are household income projections, which influence consumer preferences in ADOPT, changing?

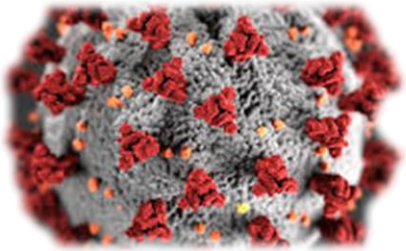
Proposed Future Research

FY 2020 (ongoing)

- Review 2019 targets and results with VTO technology managers
- Discuss target updates for 2020
- Complete ADOPT updates, including:
  - Latest AEO input assumptions and fuel price sensitivities
  - Home charging availability
- Complete additional run/review iterations with tech managers
- Q4: Milestones
  - Deliver completed LD Benefits Analysis Report for final DOE review
  - Go/No-Go: Assess priorities for year two; Input assumptions and model updates

FY 2021

- Update with new input assumptions
  - AEO **fuel prices** – expect significant changes
  - AEO emissions
  - Changes in vehicle regulations (incentives, CAFE, Greenhouse Gas Standards)
- Complete additional ADOPT updates to improve accuracy and value of benefits estimates
  - Multivehicle household impact on BEV purchases
  - Account for transportation related shifts (more **telecommuting** from COVID-19, changes in **household income** projections)
  - Feedback from tech managers and this review
- Run sensitivity analysis on key assumptions, such as fuel prices and fast charging



https://www.state.gov/coronavirus/

Any proposed future work is subject to change based on funding levels.

Summary

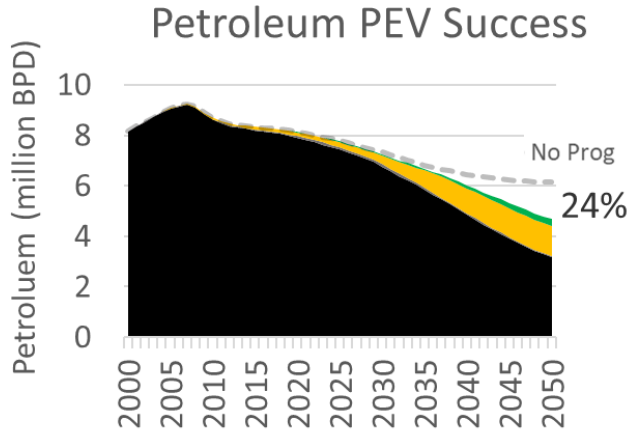
Relevance: Estimate the energy and emission benefits of R&D

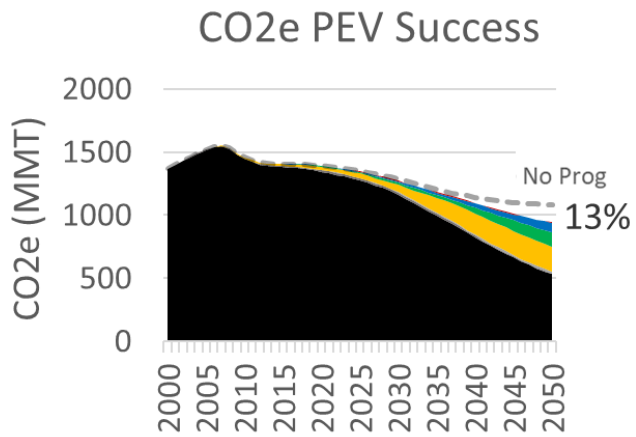
Approach: Updated and applied ADOPT
- Used a well structured and efficient modeling approach (ADOPT)
- Completed model enhancements to improve accuracy
- Implemented 2019 technical targets
- Ran No Program scenario
- Compared to technology success scenarios

Accomplishments
- Estimated annual energy and emission R&D benefits
  - Electrification (Batteries & PEEM)
  - Combustion
  - Materials
  - Fuel cells and hydrogen storage
- Collected historical data to support target updates for next round of analysis

Collaborating with VTO, BETO, HFTO, ANL and NREL

Proposed Future Research
- Continue to update assumptions, targets, and benefit estimates
- Add sensitivity analysis, such as variations in fuel prices and fast charging
- Capture vehicle choice impact of having multiple vehicles in a household
- Complete capturing impact of home charging availability





Thank You

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NREL/PR-5400-76716

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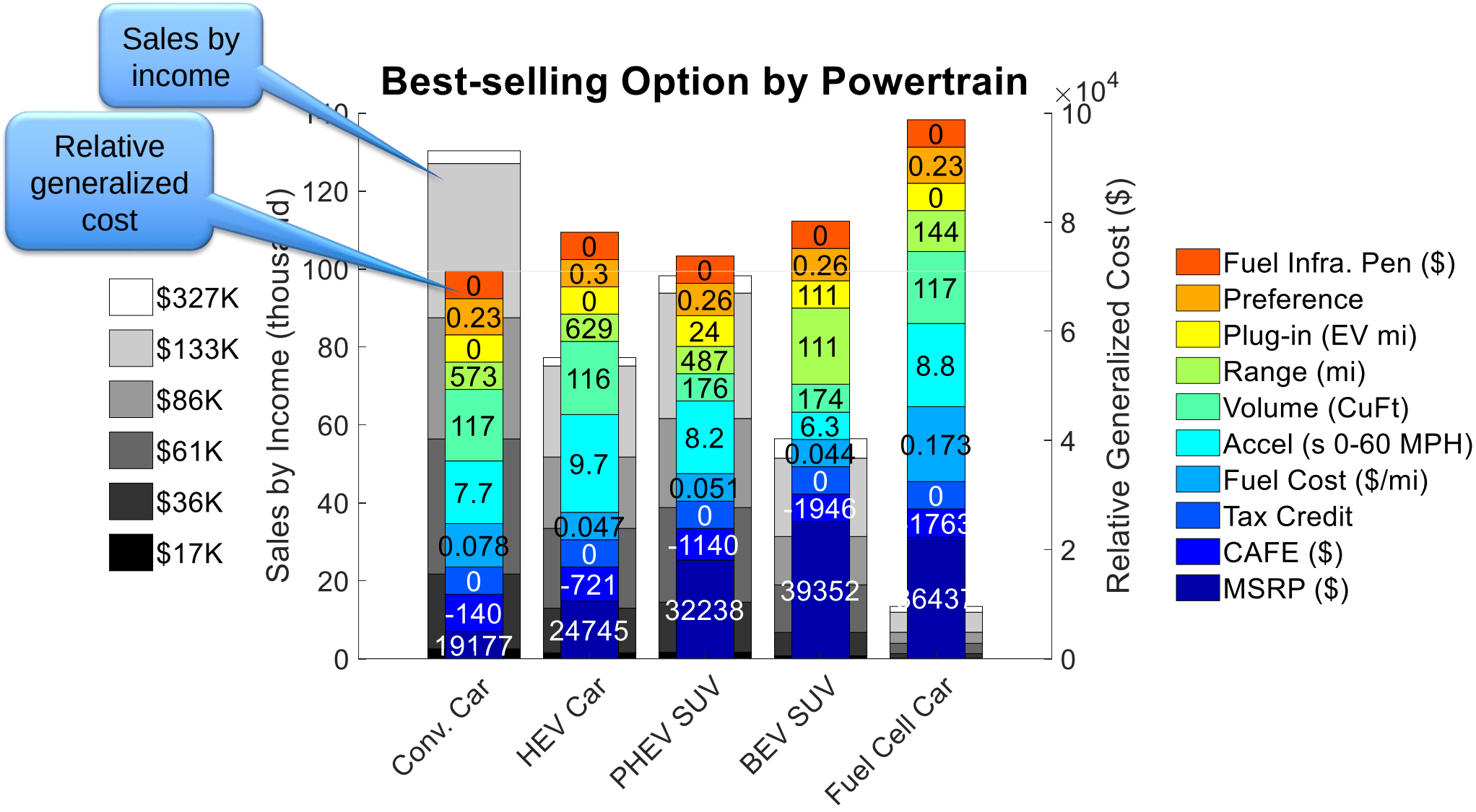
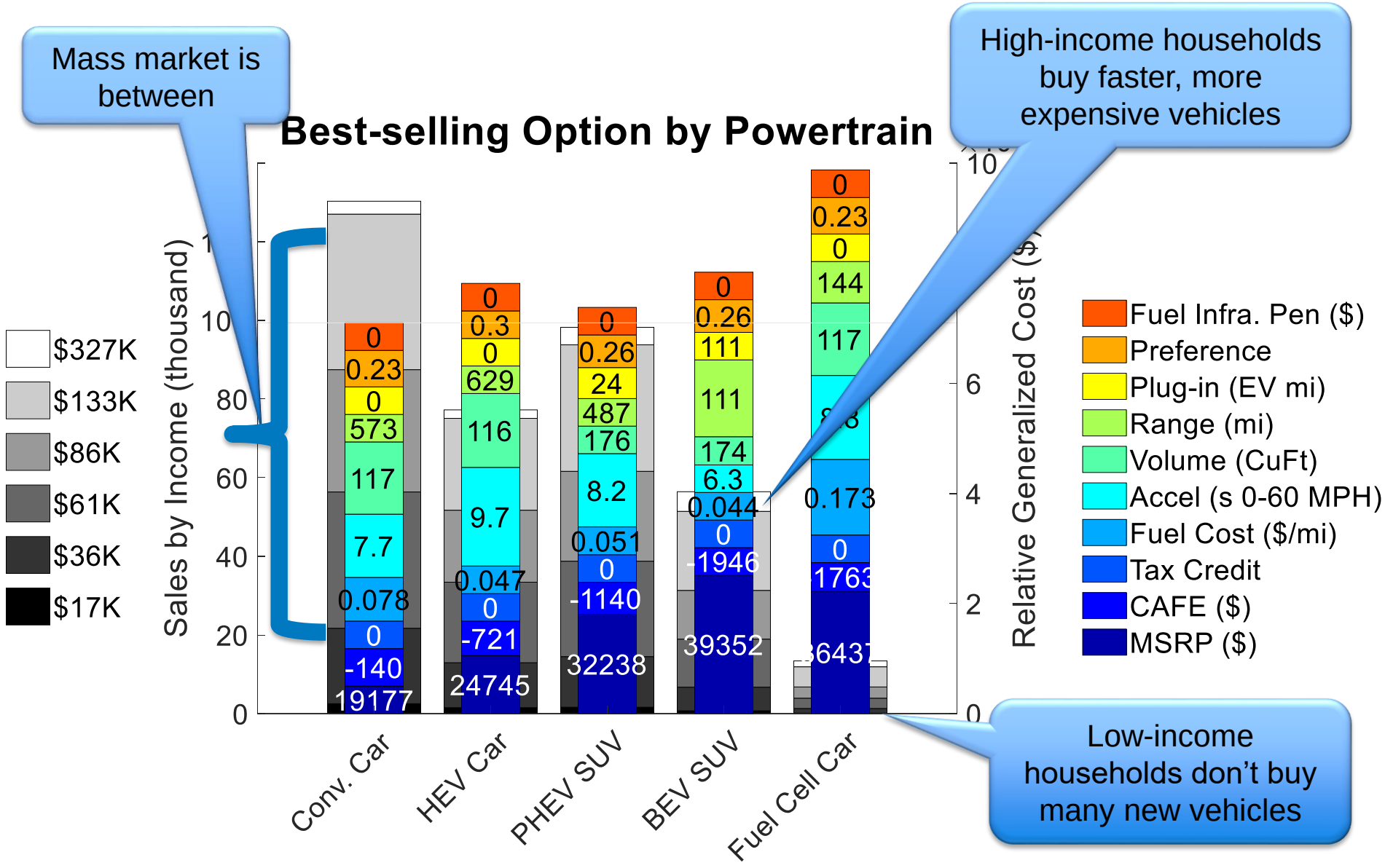
Technical Back-Up Slides

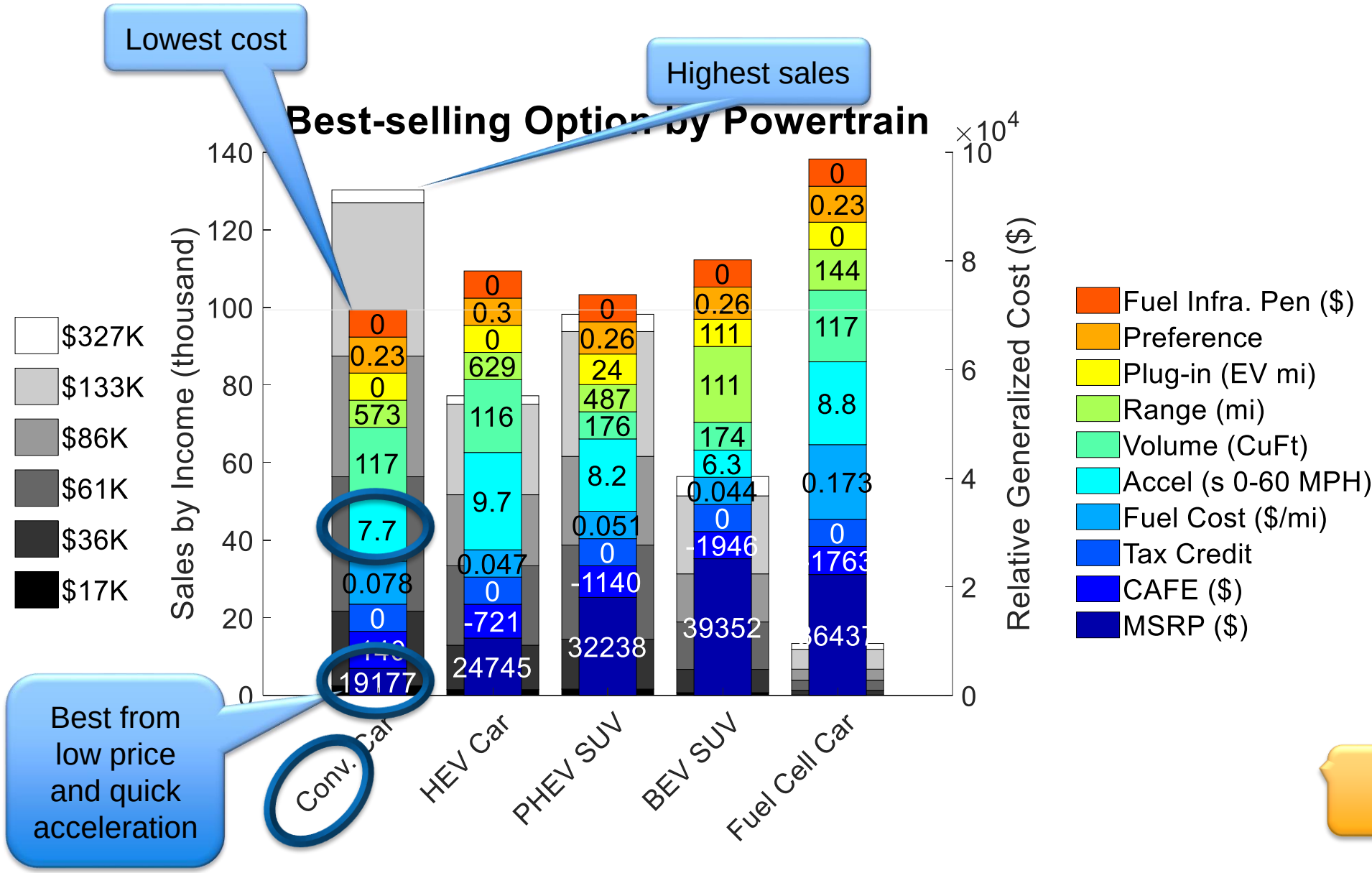
Accomplishment: 2020 Sales Explanation



Accomplishment: 2020 Sales Explanation – Income



Accomplishment: 2020 Sales Explanation



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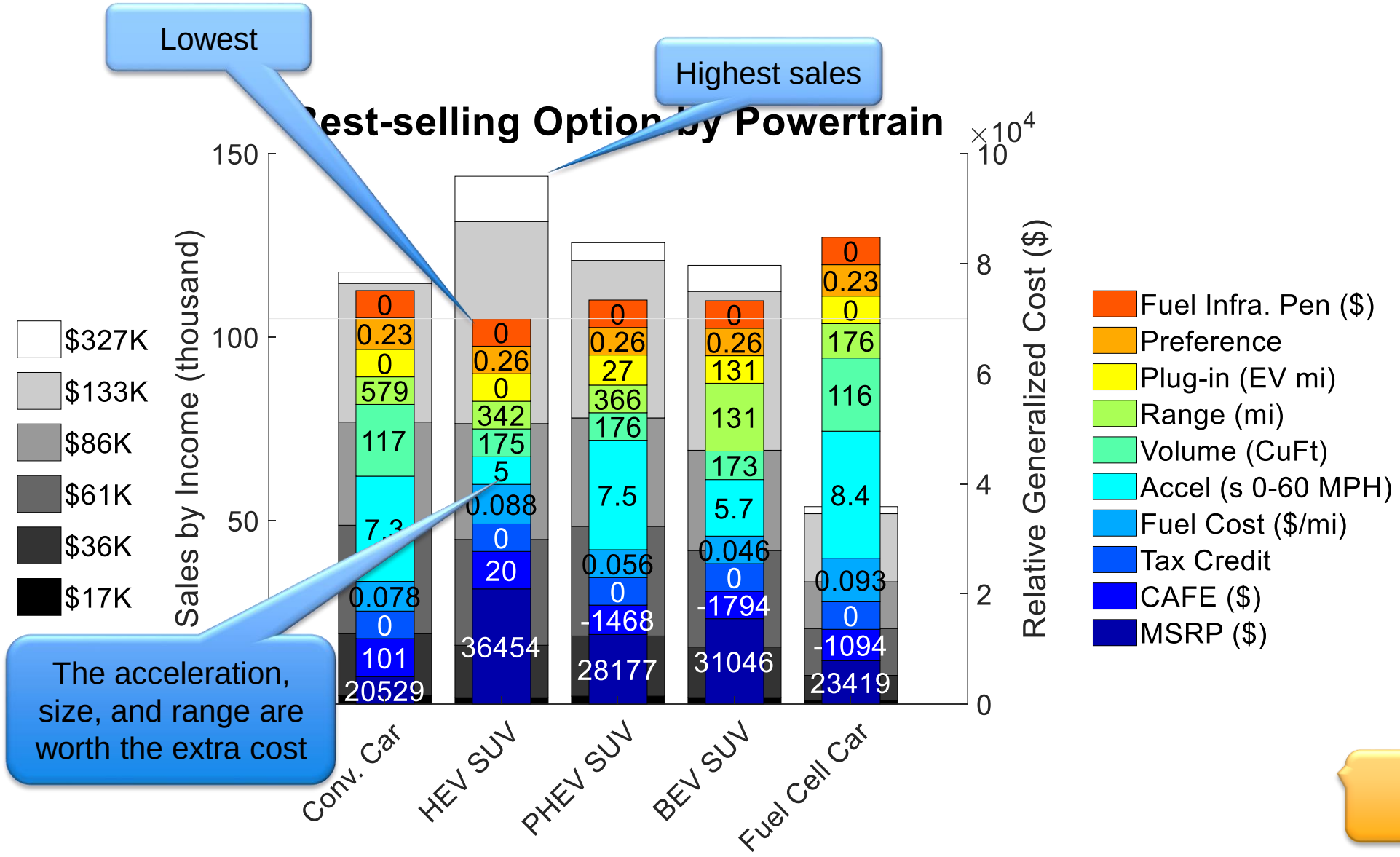
Accomplishment: 2040 HEV Sales Explanation



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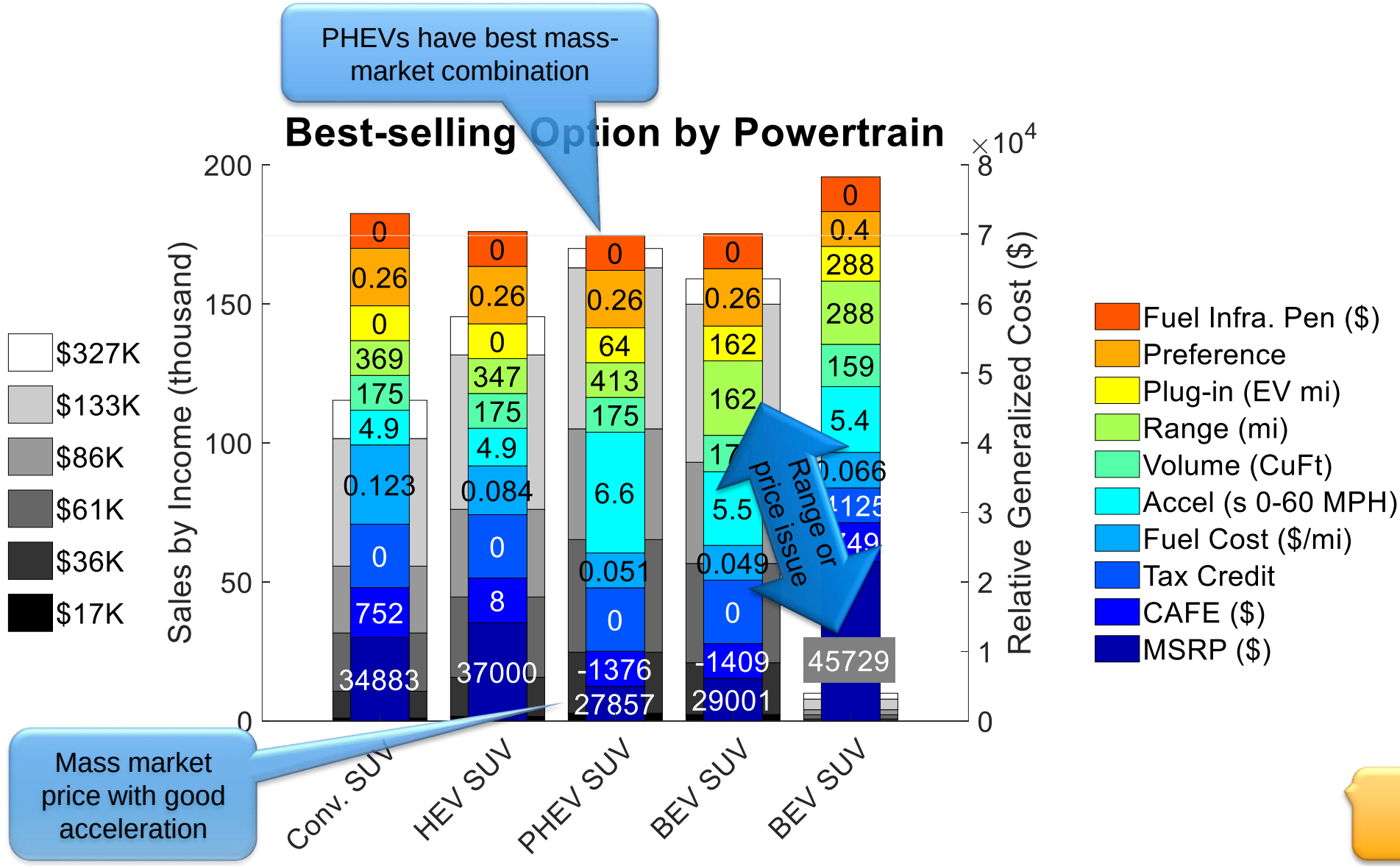
Accomplishment: 2035 PHEV Sales Explanation – Income



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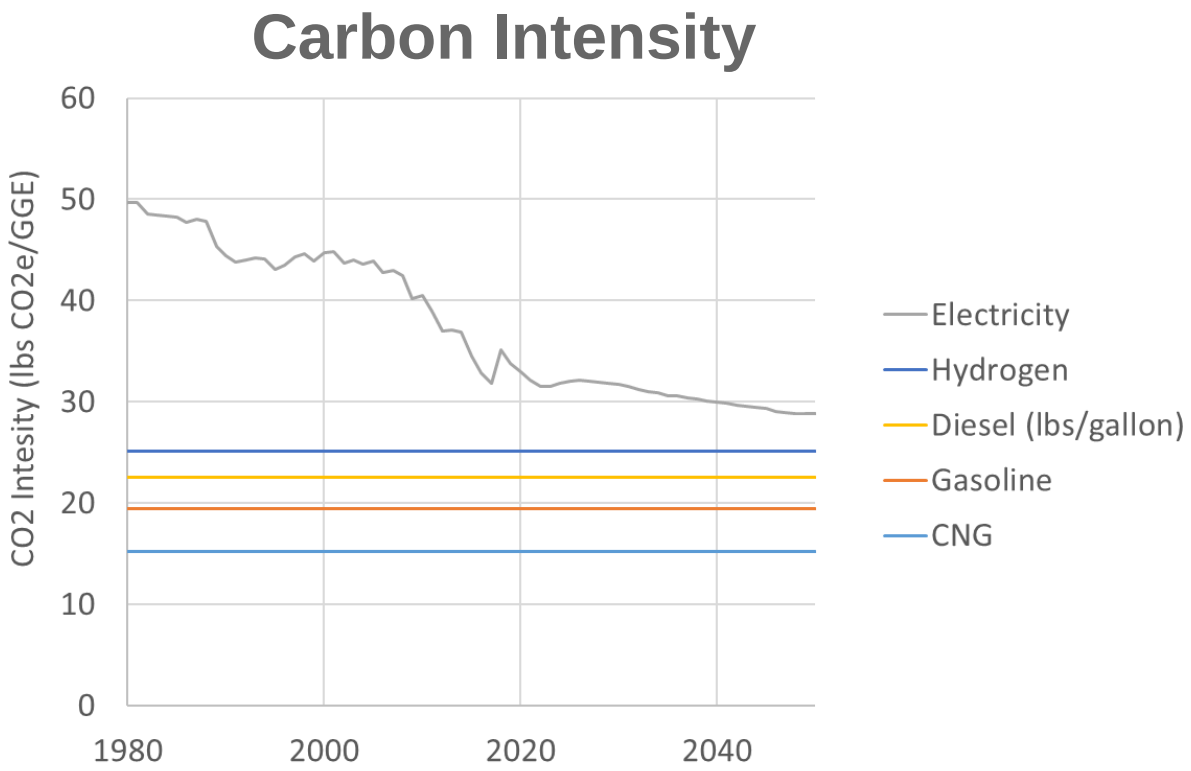
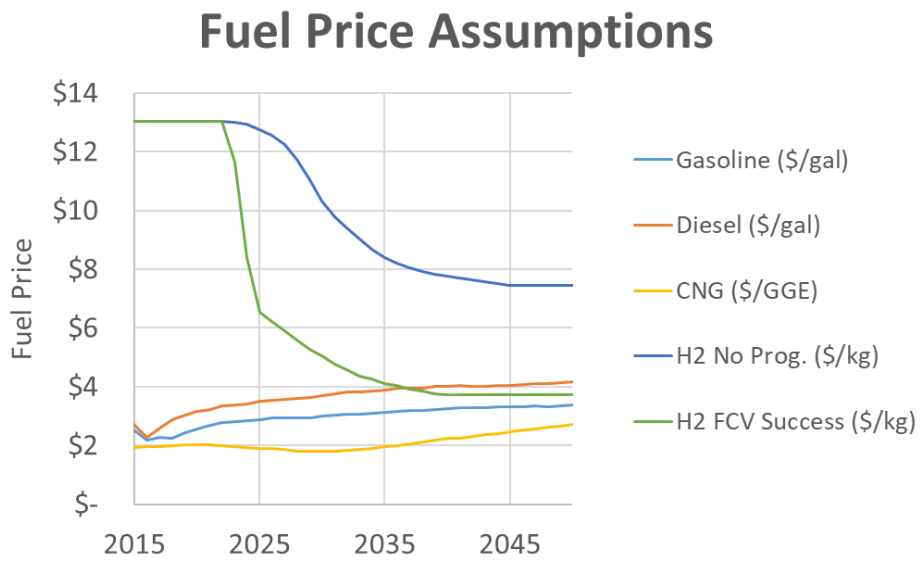
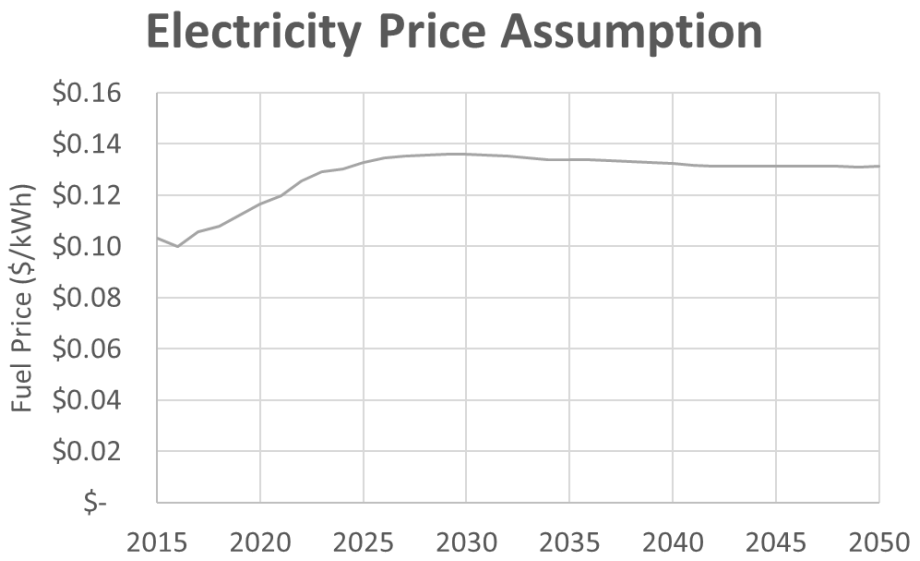
Reviewer-Only Slides

Approach: Assumptions



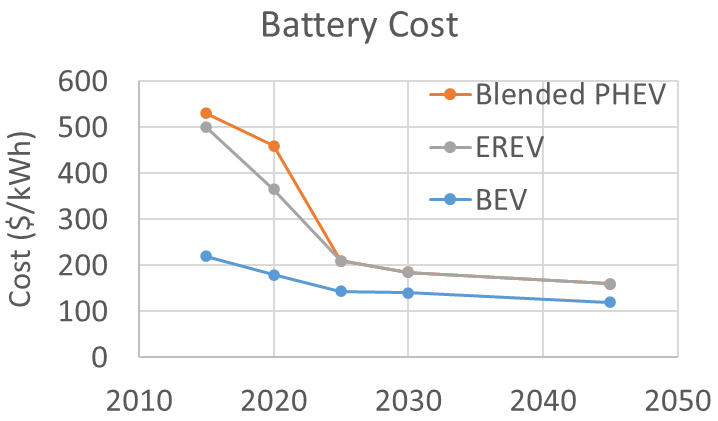


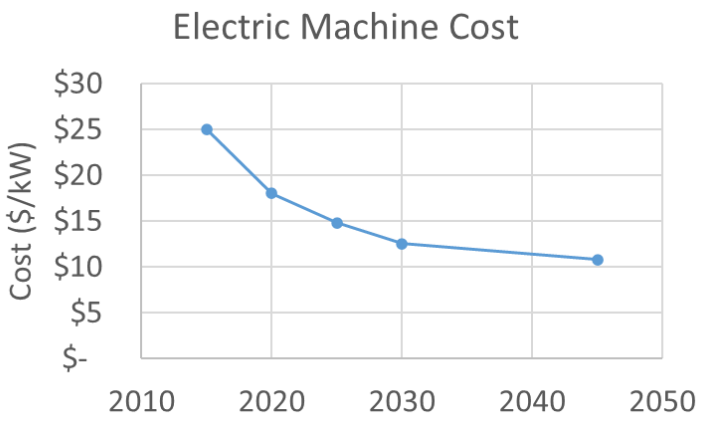


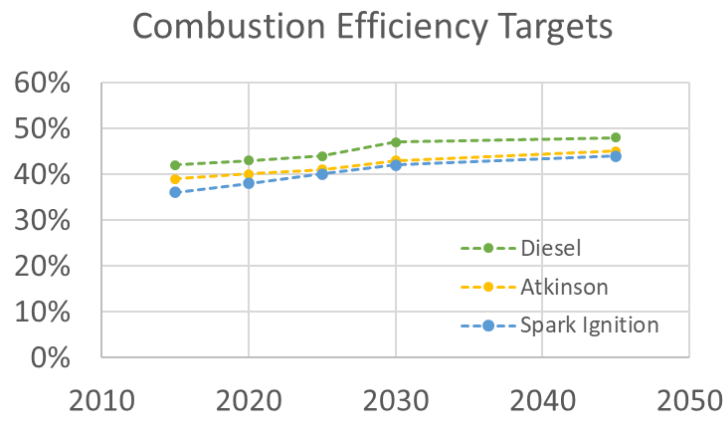
CO2e: carbon dioxide equivalent
FCV: fuel cell vehicle
GGE: gasoline gallon equivalent

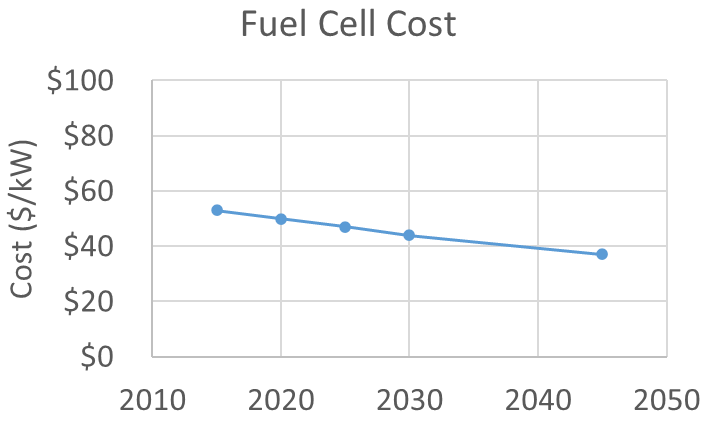
Annual Energy Outlook (AEO) reference oil price

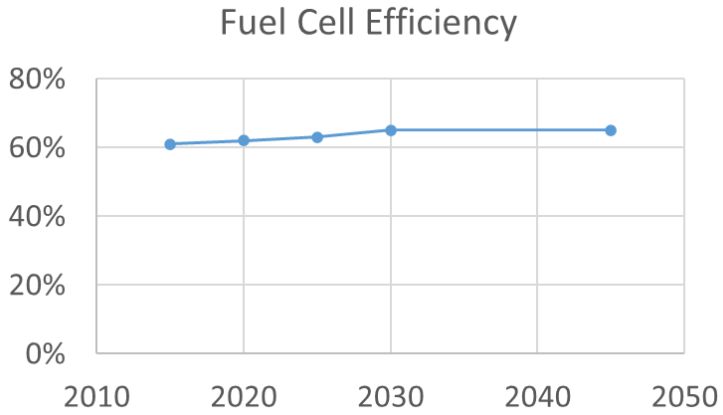
Approach: No Program Technical Target Assumption Highlights

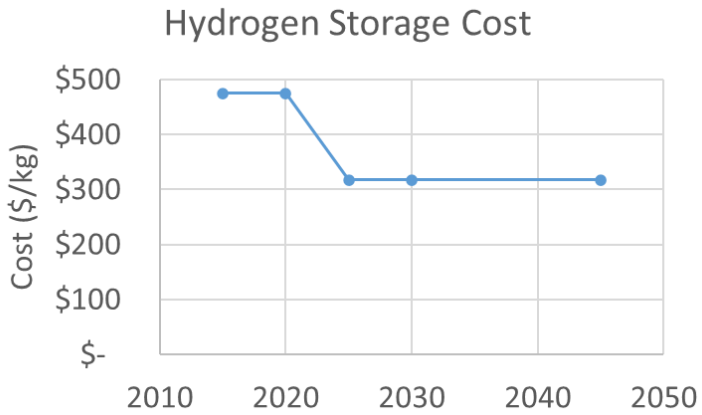








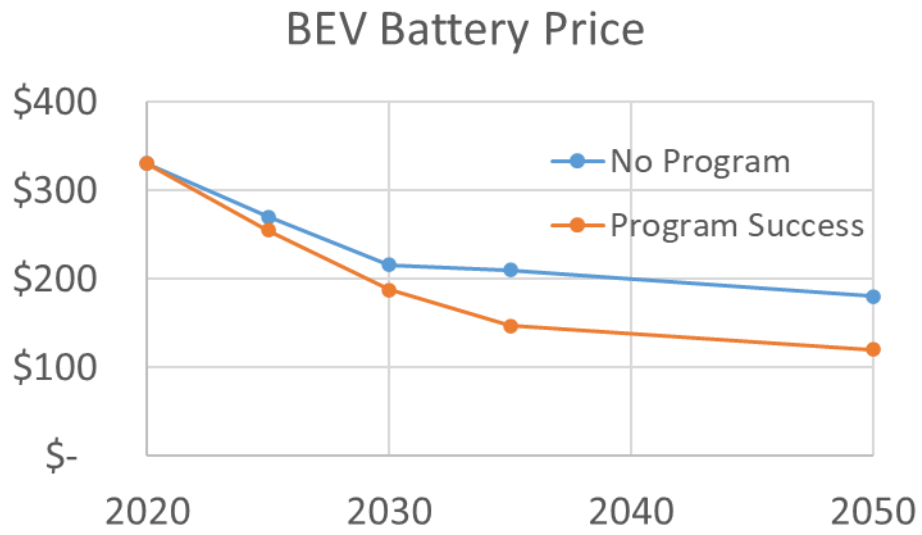


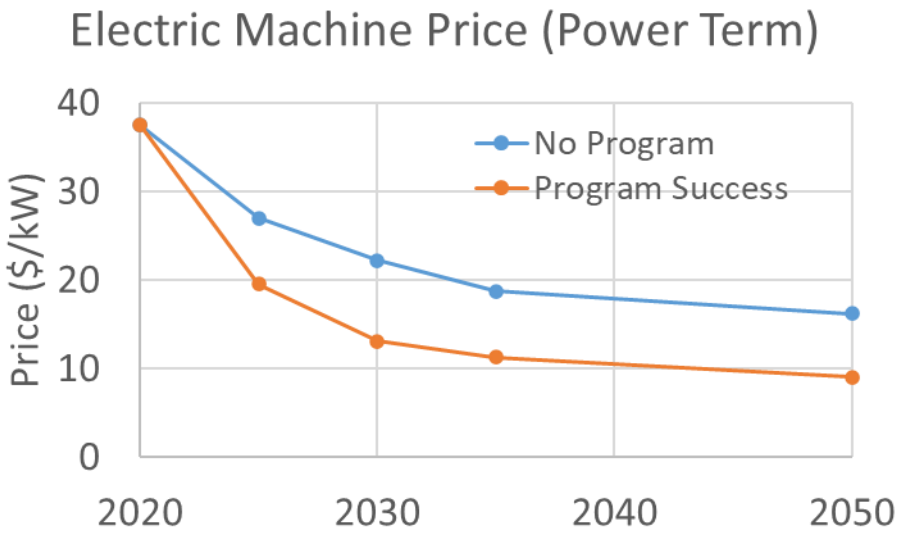


EREV: extended range electric vehicle

Approach: Electrification Target Highlights

To estimate sales:
Cost → Price (1.5x)
Lab Year → Market Year (+5)





Publications and Presentations

- Additional information on ADOPT
  - Publicly available download: www.nrel.gov/ADOPT (over 400 downloads)
  - Overview paper: https://www.nrel.gov/docs/fy15osti/63608.pdf

- Additional information on FASTSim, the vehicle powertrain model integrated with ADOPT (over 4,000 downloads)
  - Publicly available download: www.nrel.gov/FASTSim
  - Overview paper: https://www.nrel.gov/docs/fy15osti/63623.pdf

- Example publications using ADOPT for other projects
  - E. Kontou, M. Melaina, and A. Brooker, “Light-Duty Vehicle Attribute Projections (Years 2015–2030),” Report: California Energy Commission (July 2018), https://www.nrel.gov/docs/fy18osti/70455.pdf.
  - T. Theiss, T. Alleman, A. Brooker, A. Elgowainy, G. Fioroni, J. Han, S. Huff, C. Johnson, M. Kass, P. Leiby, R. Martinez, R. McCormick, K. Moriarty, E. Newes, G. Oladosu, J. Szybist, J. Thomas, M. Wang, and B. West, “Summary of High-Octane Mid-Level Ethanol Blends Study,” Report: Oak Ridge National Laboratory (July 2016), https://info.ornl.gov/sites/publications/Files/Pub61169.pdf.